Report as of FY2008 for 2008GA175B: "Assessing the impacts of a major wildfire in the Okefenokee Swamp on mercury levels in resident macroinvertebrates "

Publications

Project 2008GA175B has resulted in no reported publications as of FY2008.

Report Follows

Title: **Assessing the impacts of a major wildfire in the Okefenokee Swamp on mercury levels in resident macroinvertebrates**

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Period of Performance: **March 1, 2008 to February 28, 2009.**

Executive Summary

In 2007, a major wildfire swept through most of Okefenokee Swamp in southeastern Georgia. That habitat has a history of elevated mercury levels in aquatic biota (invertebrates, fish), and concerns developed that the fire may exacerbate the problem. This study assessed mercury levels in key aquatic invertebrates (amphipod crustaceans, dragonfly nymphs, crayfish) in areas that burned versus areas that did not burn; a study conducted prior to the wildfire provided additional reference data for comparison. Preliminary analyses do not indicate that mercury levels increased in invertebrates residing in burned areas. The study has been extended for an additional year to provide sufficient data for valid conclusions to be drawn, and has been expanded to include mosquitofish, to assess responses beyond the invertebrate community.

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PROJECT SCOPE AND OBJECTIVES

Prolonged drought conditions have emerged as the major concern affecting water resources in Georgia. If increasing prevalence of drought is symptomatic of on-going climate change, then an understanding of consequences will be imperative to effective management of Georgia's water resources. For wetlands, an important impact of drought is an increased prevalence of wildfire. In June 2007, the most expansive wildfires in recorded history occurred in the Okefenokee Swamp of southeast Georgia, and more than 75% of that wetland burned (Figure 1, Beganyi and Batzer 2009).

In terms of water quality, wildfires could have significant consequences because many wetlands, including the Okefenokee, are important sinks for mercury contaminants. Elemental mercury and methyl mercury are of particular concern for environmental safety. The methylated form of mercury is a potent neurotoxin and poses serious problems to animals in many ecosystems (Morel et al. 1998), and potentially to humans. Understanding how wildfire and drought affect mercury bioavailability in wetlands would have substantial benefits for assessing increased risk.

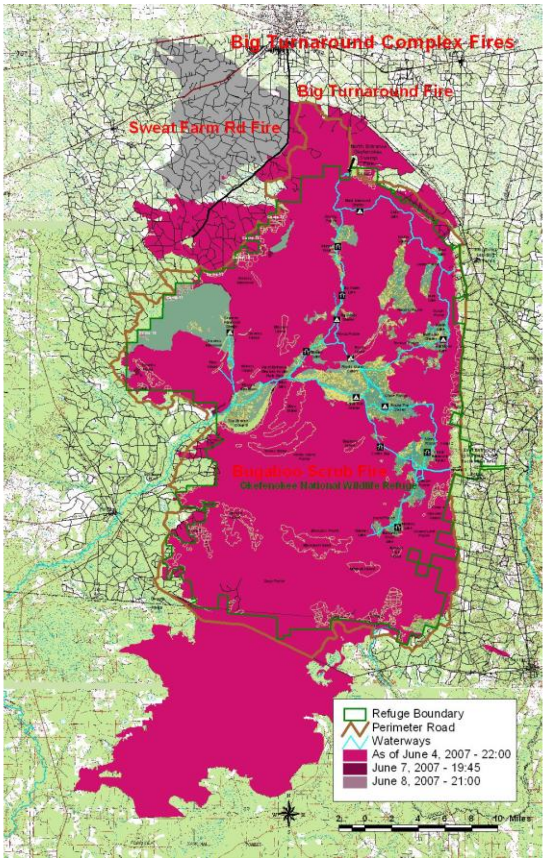

Figure 1. Map of the extent of June 2007 fires across the Okefenokee Swamp. The Big Turnaround Fire burned the northern half, and the Bugaboo Scrub Fire burned the southern half.

Even prior to the 2007 fires, the Georgia Department of Natural Resources had placed restrictions on the consumption of fish from the Okefenokee (bowfin, *Amia calva*; flier, *Centrarchus* sp.; pickerel, *Esox* spp.) due to high levels of mercury. My own laboratory established that unusually high levels of mercury occur in Okefenokee invertebrates (George and Batzer 2007), and fish probably derive mercury from these organisms. It is possible that mercury problems could become even more severe after the wildfire (Garcia and Carignan 1999, 2000).

The goal of this project is to assess whether mercury levels in Okefenokee Swamp invertebrates have increased as a result of the 2007 wildfire. That goal can be achieved because an expansive data set on mercury levels in Okefenokee invertebrates already exists, gathered from 1998 to 2000 (George and Batzer 2007), and this data set can be used as a baseline to assess fire induced change. Thus far we have collected post-fire invertebrate samples in December 2007, May 2008, September 2008, and December 2008.

REVIEW OF PAST RELEVANT WORK

Past Work on Mercury Contaminant in Wetlands

Burning of fossil fuels, medical waste incineration, agriculture, and mining are all important sources of mercury to the environment (Rood et al. 1995). Emissions significantly increase mercury levels in precipitation (Rolfhus and Fitzgerald 1995, Keeler et al. 1995), and the material accumulates in wetlands (Moore et al. 1995, Rood

1996, St. Louis et al. 1996, Heyes et al. 1998, Niamo et al. 2000). Fire and direct drying of sediments from drought may remobilize mercury from sediments and peat, increasing mercury bioavailability to biota (Hall et al. 1998, Lamontagne et al. 2000, Snodgrass et al. 2000).

Bioaccumulation of mercury by invertebrates allows mercury to become available to organisms higher in the food chain (Liu et al. 2008). Wetland fish can bioaccumulate particularly high levels of methyl mercury (Bloom 1992, Mason et al. 1994, Kannan et al. 1997, Wong et al. 1997, Hall et al. 1998). As a result, piscivorous birds are exposed to bioavailable mercury (Gariboldi et al. 1997). Since alligators are long-lived wetland predators, there are also concerns about the potential to bioaccumulate mercury in their tissues (Jagoe et al. 1998, Khan and Tansel 2000). Game fish, birds, and alligators are all organisms of concern in the Okefenokee, and invertebrates and mosquitofish are likely involved in the food chains for each.

Past Work in the Okefenokee

Invertebrates are useful bioindicators of environmental conditions (Rader et al. 2001), and thus in 1998 a project was initiated to assess spatial and temporal variation of mercury levels in Okefenokee invertebrates (George and Batzer 2007). In that two year study, 32 sites were chosen in the Okefenokee that were distributed across the range of hydrological units and vegetative communities present in the swamp. They included sites centered around Chesser/Grand Prairie, Double Lakes, Durden Prairie, Chase Prairie, Floyd's Prairie, and Billy's Lake. At each site, sampling was stratified to include shrub thickets, marsh prairies, cypress stands, boat trails, and deepwater lakes or canals. Sampling was conducted in December 1998, May 1999, August 1999, December 1999, May 2000, and August 2000. At each sampling location, amphipods (Crangonyctidae) were collected as available for 30 minutes using sweep nets. Beginning in May 1999, Odonata nymphs (primarily Anisoptera) were collected, and beginning in December 1999, crayfish (Cambaridae) were added to collections. Invertebrates were placed in plastic vials and transported on ice back to the laboratory, and then frozen. Total mercury levels were determined using Atomic Absorption Spectrophotometery (AAS) as described by Waldrop (1999). Validation trials were conducted and lower detection limit was 0.25 ppb.

Mercury levels varied dramatically among sample pools (averaged 1.6 ppm, but ranged from 0 to 86 ppm), and a 4-way ANOVA model concurrently addressing location, sub-habitat, sample date, and study organism accounted for 65.1% of this variation. However, the kind of organism ($F_{2, 184} = 93.07$, $P < 0.0001$) and the sample date ($F_{5, 184} = 16.16$, $P < 0.0001$) were the only significant factors in the model, with the study organism and sample date accounting for 43.3% and 18.8% of variation, respectively. Mercury concentrations were dramatically higher in amphipods than either odonates or crayfish (Figure 2). Levels varied temporally with the highest levels of mercury occurring in May 2000. Overall levels of mercury were similar among all six locations ($F_{5, 184} = 1.67$, $P = 0.1448$) and all five subhabitats ($F_{4, 184} = 1.67$, $P = 0.3527$). These analyses suggest that, while no "hot spots" for mercury were detected, there were "hot times" and "hot organisms" (see also Liu et al. 2008). The lack of spatial variation in mercury across the Okefenokee is consistent with aerial deposition of the material relatively evenly across the wetland (Fitzgerald et al. 1998).

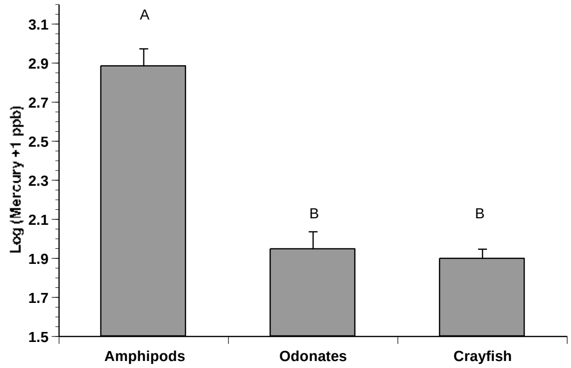

Figure 2. Mercury levels (mean ± SE)omn 1998-2000 for amphipods, odonates, and crayfish across the Okefenokee Swamp, with levels being significantly higher in amphipods than other taxa (ANOVA, Tukey test, $P < 0.05$)

Levels of mercury detected in Okefenokee aquatic invertebrates seemed unusually high, even for wetlands. We frequently encountered mercury levels in excess of 20 ppm, and levels averaged 1.6 ppm. In comparison, mercury levels in invertebrates of the Florida Everglades averaged 0.3 ppm (Scheidt 2000), and levels averaged 0.1 ppm in small depressional wetlands in South Carolina (Snodgrass et al. 2000). However, the higher than normal mercury levels detected in this study may not necessarily indicate a uniquely severe problem for the Okefenokee Swamp. The high levels occurred almost exclusively in amphipods, and these organisms are often not collected in other studies of mercury in wetland invertebrates. Amphipods might be especially useful for detecting high levels of mercury because, as Sferra et al. (1999) reported, mercury toxicity in amphipods can exceed 4.1 ppm. Many organisms might die before accumulating such high levels. It follows that since amphipods are often a major source of food for fish they might be contributing to the high levels of mercury in Okefenokee Swamp fish.

METHODS

The Okefenokee Swamp is one of the largest freshwater wetlands in North America. It is approximately 3,800 km^2 and provides habitat for a variety of aquatic organisms including fish, reptiles, birds, and invertebrates (Porter et al. 1999, Kratzer and Batzer 2007). The Okefenokee Swamp has many characteristics that could lead to mercury accumulation and bioavailability problems, including high water temperature, frequent anoxic conditions, low pH (< 4.0), intermittent hydrology, peat deposits, and periodic fire (Mason et al. 2000).

After the 2007 wildfire, I selected 21 sites for post-fire sampling, all located in the same six general areas sampled before the fire (Figure 3, Beganyi and Batzer 2009). Thirteen of the sites had burned (5 cypress stands, 5 scrub-shrub thickets, 3 marsh prairies) and 8 had not (3 cypress stands, 3 shrub-shrub thickets, 2 prairies). Sites were sampled in December 2007, May 2008, September 2008, and December 2008, which corresponds to the seasonal schedule of past efforts. Amphipods (Cragonyctidae), odonates (Libellulidae), and crayfish (Cambaridae) were collected with nets and dip pans for 1 person/ hour. Total mercury levels in these samples are being determined by the UGA CAES Soils and Environmental Testing Laboratory using Atomic Absorption

Spectrophotometery (AAS), although the procedures have been up-dated from those used previously. Standard quality control steps are being conducted including validation trials in conjunction with each sampling run.

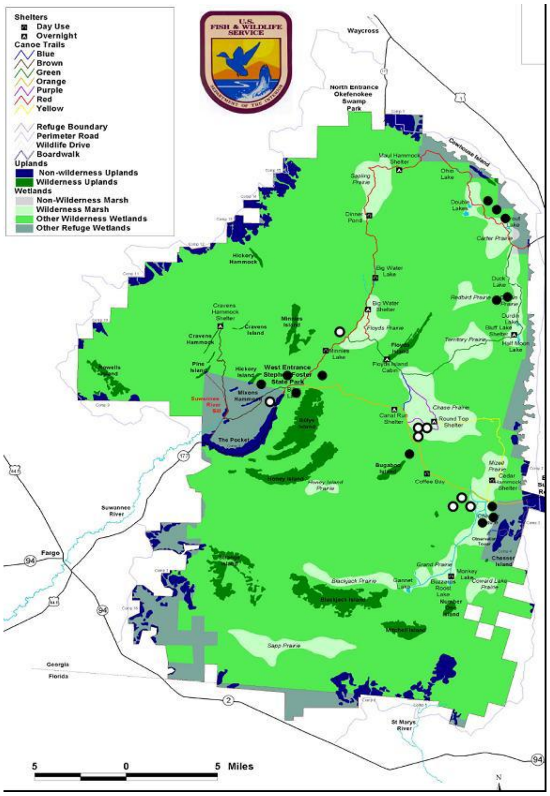

Figure 3. Locations of sites sampled in 2007 and 2008, and proposed for 2009. Closed circles are in areas that burned and open circles are in areas that did not (see Figure 1).

RESULTS

Analyses of mercury levels are on-going, but I can provide some preliminary findings (see also Beganyi and Batzer 2009). All data on mercury levels in invertebrates collected from December 2007 through December 2008 are listed in Appendix 1. As prior to the fire, total mercury levels appear higher in amphipods than in odonates or crayfish. Also as earlier, temporal variation is pronounced, with levels varying from December 2007 to September 2008 ($P = 0.0002$, Figure 4). However, at this point, I have no compelling evidence that mercury levels are higher in invertebrates living in burned areas compared to residual non-burned areas (Figure 4, Appendix). Additionally the high levels of mercury in invertebrates detected in baseline sampling in 1998-2000 do not seem to be re-occurring in 2007-2008. The possibility that mercury levels in aquatic invertebrates declined, rather than increased, after the fire needs further exploration. Also because temporal variation in mercury levels is natural, additional sampling planned for 2008-2009 will provide a more complete picture.

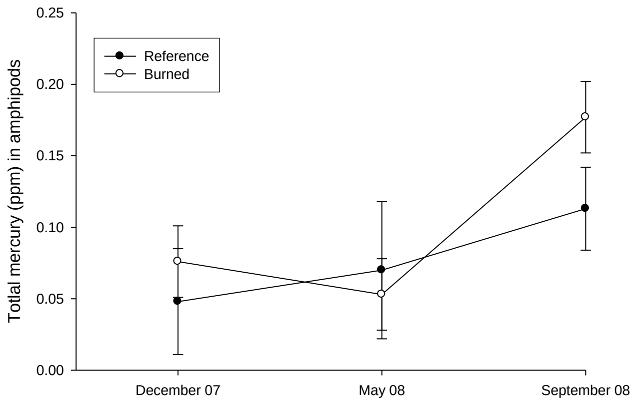

Figure 4. Preliminary data on post-fire total mercury levels in amphipods in areas that burned vs. residual areas that did not burn.

CONCLUSIONS AND RECOMMENDATIONS

Preliminary analyses do not indicate significant change in total mercury levels in any of the invertebrates sampled. The project has been extended to include May and September 2009 to enable analysis of a full two-year-long invertebrate data set. Additionally sampling in May and September 2009 will be extended to include mosquitofish (*Gambusia* spp.) to begin to assess possible mercury bioaccumulation problems in the fish community of the Okefenokee. Finally, analyses of the responses of overall invertebrate communities to the fire are also now part of the continuing project.

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APPENDIX. Total mercury (Hg) levels (ppm) in individual sample pools of invertebrates (amphipods, odonates, crayfish) collected from in burned and non-burned reference habitats (12/2007 to 12/2008).

	Burned Hg (ppm)			**Reference Hg (ppm)**		
	Amphipods	**Odonates**	**Crayfish**	**Amphipods**	**Odonates**	**Crayfish**
Prairie	0.555	0.012	0.018	0.045	0.011	0.032
	0.141	0.012	0.015	0.065	0.038	0.041
	0.149	0.021		0.065	0.035	0.020
	0.017			0.000	0.016	
	0.046			0.018		
	0.032			0.023		
	0.000					
	0.000					
	0.027					
Shrub	0.101	0.024	0.028	0.077	0.022	0.018
	0.194	0.024	0.009	0.108	0.030	0.022
	0.102	0.021	0.035	0.088	0.027	0.021
	0.028	0.014	0.008	0.019	0.033	0.013
	0.068	0.017	0.011	0.077	0.012	0.000
	0.058	0.021	0.015	0.044	0.028	0.034
	0.062	0.003	0.010	0.057		
	0.058	0.026	0.014	0.035		

	0.000	0.046				
	0.036	0.012				
	0.025	0.019				
	0.029	0.019				
		0.014				
		0.022				
Cypress	0.186	0.028	0.029	0.103	0.053	0.046
	0.097	0.030	0.018	0.283	0.109	0.080
	0.073	0.018	0.014	0.138	0.035	0.061
	0.104	0.040	0.032	0.036	0.023	0.016
	0.245	0.020		0.045	0.042	0.028
	0.068	0.015		0.166	0.034	0.041
	0.050	0.010		0.034	0.021	0.031
	0.167	0.018		0.052	0.032	
	0.132	0.015			0.031	
	0.172	0.000			0.047	
	0.076	0.031				
	0.181	0.022				
	0.027	0.031				
	0.025					
	0.103					
	0.023					
	0.062					
	0.028					
	0.055					
Average	0.090	0.020	0.018	0.072	0.034	0.032
SD	(0.097)	(0.010)	(0.009)	(0.062)	(0.021)	(0.020)